Rev	Date	Description	Prepared by:		
0	10/3/14	Orig	***John F. Bradley, S.E.*** Arizona Registered Structural Engineer Lic. #36412 Atascadero, California	JOB NO.	2408160
				SHT	1 OF 17
				DATE	10/3/2014
			FOR: Hopper H1 (270 cu ft Capacity)	DES. BY	JFB
			DESCRIPTION: Design of Vessel & Supports	REV	0

STRUCTURAL CALCULATIONS FOR

Hopper H1 (270 cu ft Capacity)

Design of Vessel & Supports

Double Wall Stainless Steel

14.17 ft x 8.25 ft x 7 ft Tall Supported by Concrete Vault

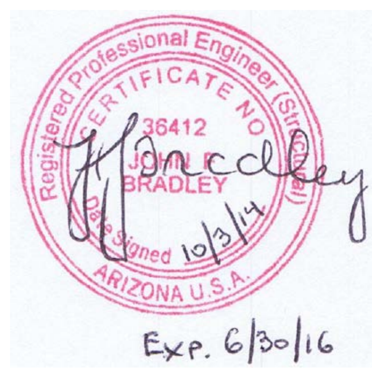
REVISION 0

Dated October 03, 2014

(Original Calc Package)

LOCATED AT

Parker, Arizona



Calculations Prepared For:

Evoqua Water Technologies

2523 Mutahar Street

Parker, AZ 85344

Ph (928) 669-5758, Fax (928) 669-5775

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Design Summary

Product Stored:	Spent Activated Carbon (Design for Both Liquid Slurry & Dry Granular Material)
Specific Gravity:	1.50
Max Temperature:	150^{o} F
Design Pressure:	Atmospheric
Design Codes:	1) API 650 11th Edition
	2) IBC 2012 for Seismic
Wind Design:	Vessel is indoors; wind is not considered
Seismic Design:	IBC 2012: S_S = 0.23g, S_1 = 0.15g, I_e = 1.5, Site Class D

Description

This vessel is a double-wall inverted pyramid hopper for use inside a water treatment plant near Parker, Arizona. Product is spent activated carbon granular material (both liquid slurry and dry granular material). Material used for the tank construction is SS304 stainless steel except for the inner shell in contact with product which is SS316. Inner shell is separated from outer shell by (12) evenly spaced bent plate channel spacers @ 1 1/2" tall. These spacers are attached to inside of outer shell. Inner shell is 3/8" thick SS316 plate, and outer shell is 1/4" SS304 plate.

Design Criteria

Specific gravity of product is provided by customer at 1.50 (conservative). Tank is designed for atmospheric pressure (no internal pressure or vacuum) and ambient temperature. Design codes used for this tank are API 650 and IBC 2012. There are no American codes that specifically address all components of hoppers, so other codes & design procedures will be used as appropriate. Allowable steel stresses are taken per API 650. Wind and seismic loads are calculated both per IBC 2012, and load combinations are taken per IBC 2012. Seismic design values above are from USGS website for Parker, AZ.

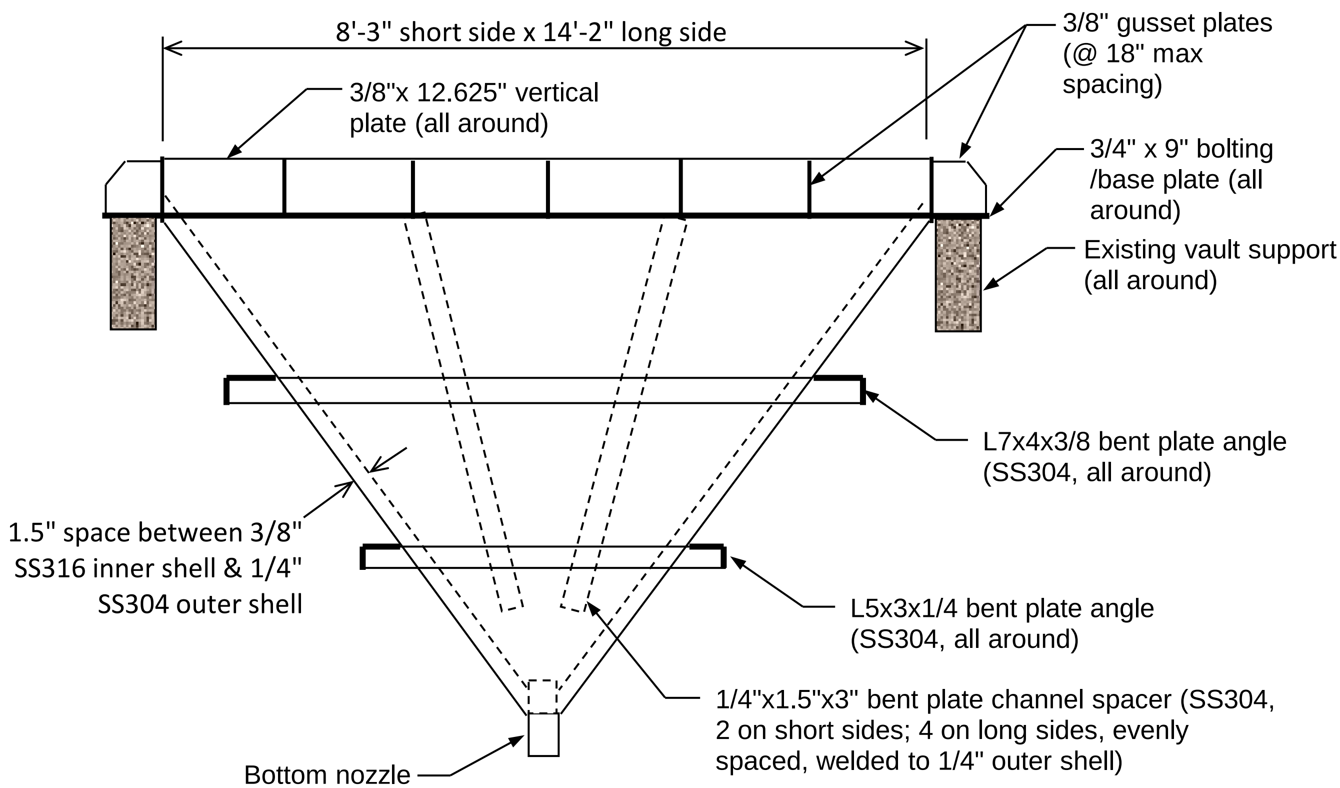
Design Methodology

The Inner tank shell is the normal pressure boundary; the outer tank is used for leak containment. Under normal loading, inner shell transfers loads to the outer shell at discreet locations of spacers. In event of leak in inner shell, space between the two shells may fill up, subjecting the outer shell to uniform product pressure. This full product pressure could only be developed for liquid slurry condition, but 5' head on dry product will conservatively be considered for design of both the inner and outer shell. Vessel is supported at a stiffened rectangular compression bar (base plate) at top of vault walls, and vessel is anchored to tops of these walls.

Vessel is replacing an similar existing hopper at same location. Vessel is supported on (3) walls of a concrete vault, and by an HSS8x8 along one (short) side. Existing anchor bolts are corroded and will be cut off and not reused. New epoxy anchors will be installed in existing concrete walls and welded to existing HSS tube. Check of existing concrete vault is beyond the scope of these calcs, but it should be adequate as hopper is being replaced in kind. For lateral load calculations, it is assumed that tank is a pendulum-type structure rigidly supported at anchor plates. For seismic OTM calculations, product head above the anchor bolt circle is conservatively ignored.

Design Criteria & Sketch

Product Stored:	Spent Activated Carbon (Design for Both Liquid Slurry & Dry Granular Material)
Specific Gravity:	1.50
Max Temperature:	150^{o} F
Min Design Metal Temp:	-20^{o} F
Design Pressure:	0 psig (atmospheric)
Corrosion Allowance:	0 in
Design Codes:	1) API 650 11th Ed.
	2) IBC 2012 for Wind & Seismic
Seismic Design:	S_S = 0.23g, S_1 = 0.15g, F_a = 1.60, F_v = 2.40, I_e = 1.5, Site Class D
	Seismic Design Category B
Wind Design:	Not Required



Weights: Empty Vessel = W_{empty} =	7.5	k
Product in tank (full to grating level) =	25.3	k
Tank + operating product = W_{full1} =	32.8	k
5' head of dry product above top of grating =	54.7	k
Tank + operating product + head = W_{full2} =	87.5	k

IBC 2012 Seismic Design Loads

IBC 2012 Seismic Design Loads: (ref ASCE 7-10 Sections 13 & 15)

Governing Seismic Design Acceleration:

Horizontal:	$A_i = (0.4a_pS_{DS}I_p)[1+2(z/h)]/R_p$ =	0.059 g		(Eq 13.3-1)
	or, $A_i = 0.3S_{DS}I_e$ =	0.110 g	GOVERNS	(Eq 15.4-5)
	Where: $S_{DS} = (2/3)F_aS_s$ =	0.245		
	F_a =	1.600		
	S_s =	0.230		
	a_p =	1.0		
	R_p =	2.5 (per ASCE 7-10, Table 13.6-1)		
	$I_e = I_p$ =	1.50		
Vertical:	$A_v = 0.2S_{DS}I_p$ =	0.074 g		

Base Shear: (ref ASCE 7-10 Eq. 12.8-1)

Vessel full:	$V_{s\text{-}full} = A_iW_{full2}$ =	**9.66 k**	GOVERNS
	Where: Design acceleration = $A_i = C_s$ =	0.110 g	
	W_{full2} =	87.50 k	
Vessel empty:	$V_{s\text{-}empty} = A_iW_{empty}$ =	**0.83 k**	
	W_{empty} =	7.50 k	

Overturning Moments (at anchor plate level):

Vessel full:	$M_{s\text{-}full} = (V_{s\text{-}full})(CG_{full})$ =	**16.91 ft-k**	GOVERNS
	Where: CG_{full} =	1.75 ft (below top of vault / anchor plate)	
Vessel empty:	$M_{s\text{-}empty} = (V_{s\text{-}empty})(CG_{empty})$ =	**1.45 ft-k**	
	Where: CG_{empty} =	1.75 ft	

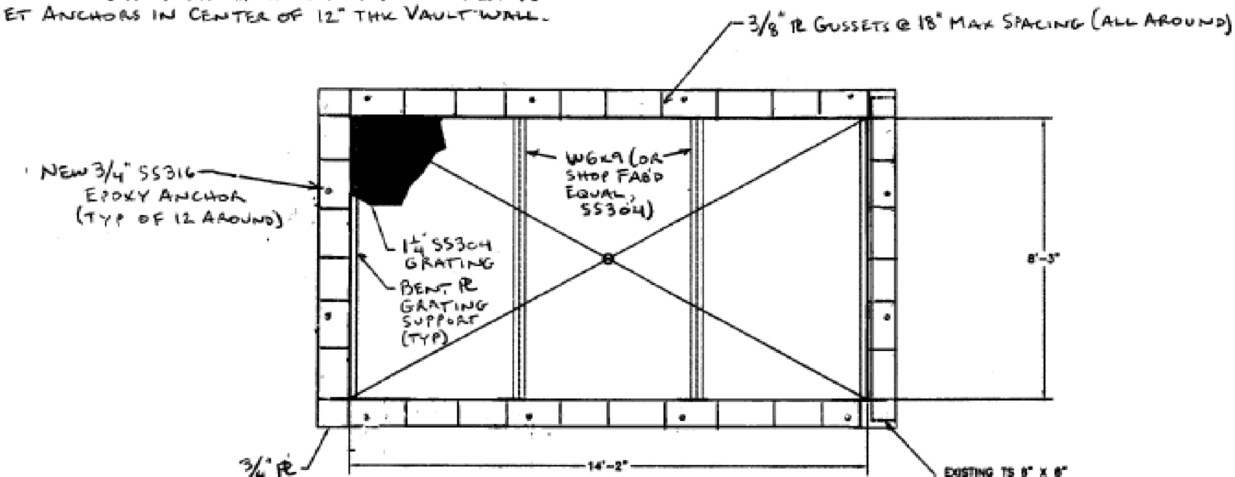
Resisting Moments (at anchor plate level, conserv. ignore product head above grating):

Vessel full:	$M_{resist} = (0.6)(W_{full1})(8.25/2)$ =	**81.18 ft-k**
Vessel empty:	$M_{resist} = (0.6)(W_{empty})(8.25/2)$ =	**18.56 ft-k**

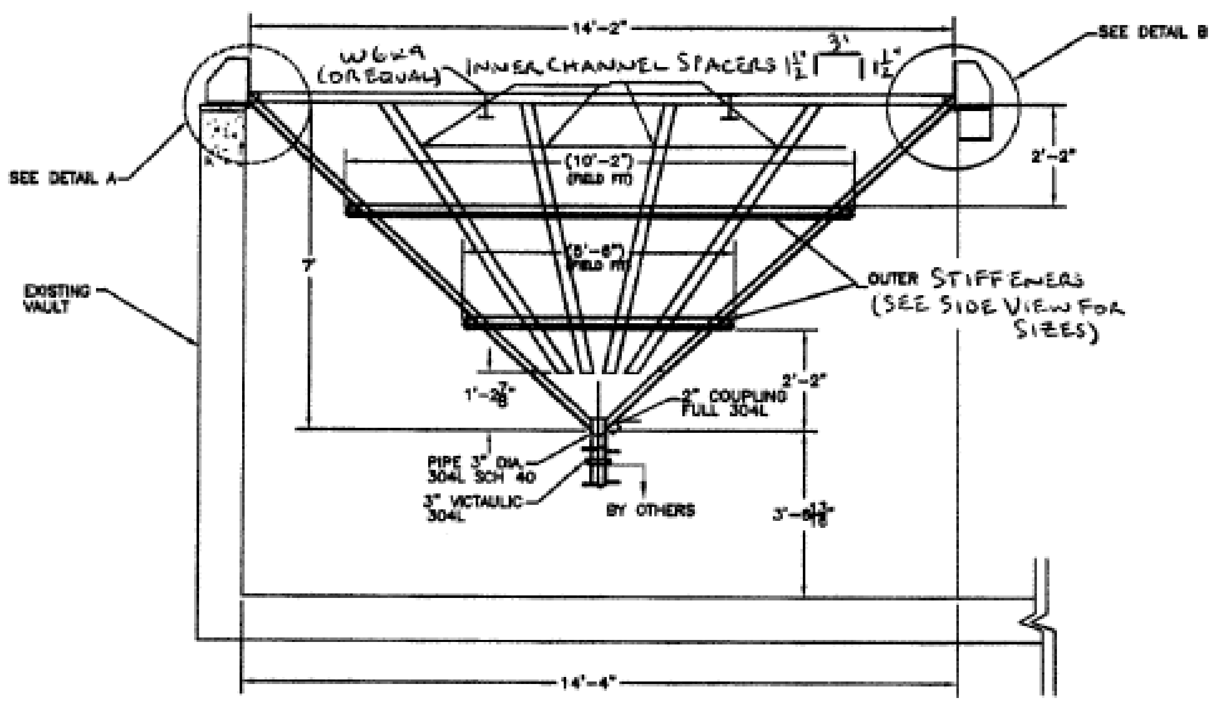
(Since OTM < resisting moment, hopper is stable for seismic overturning)

Hopper Details

NOTES:
1) CUT EXISTING CORRODED STUDS FLUSH W/ TOP OF VAULT WALLS.
2) FIELD DRILL & INSTALL (12) NEW HILTI EPOXY ANCHORS IN LOCATIONS SHOWN AFTER HOPPER IS SET IN PLACE. SET ANCHORS IN CENTER OF 12" THK VAULT WALL.

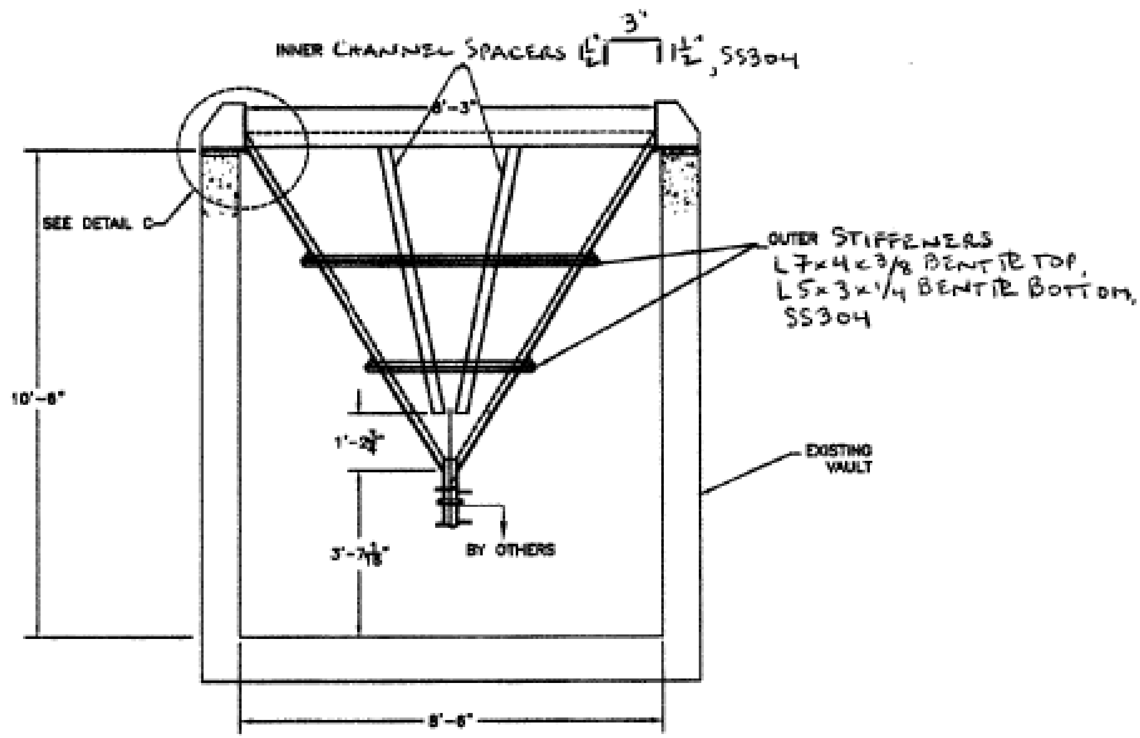


PLAN VIEW

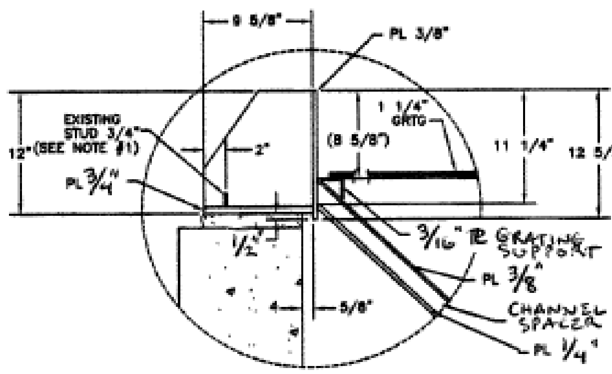


FRONT VIEW

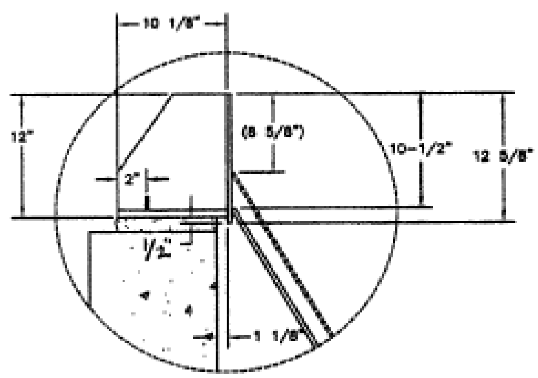
Hopper Details, cont.



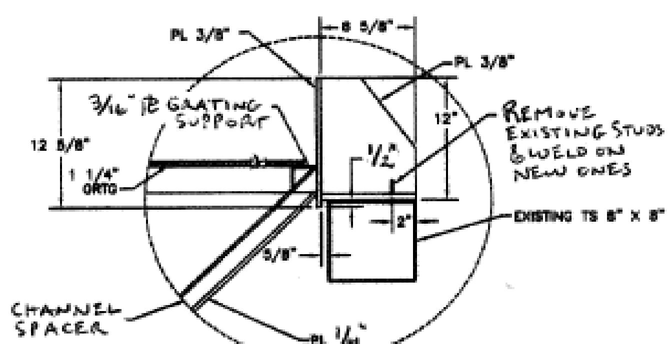
SIDE VIEW



DETAIL -A-

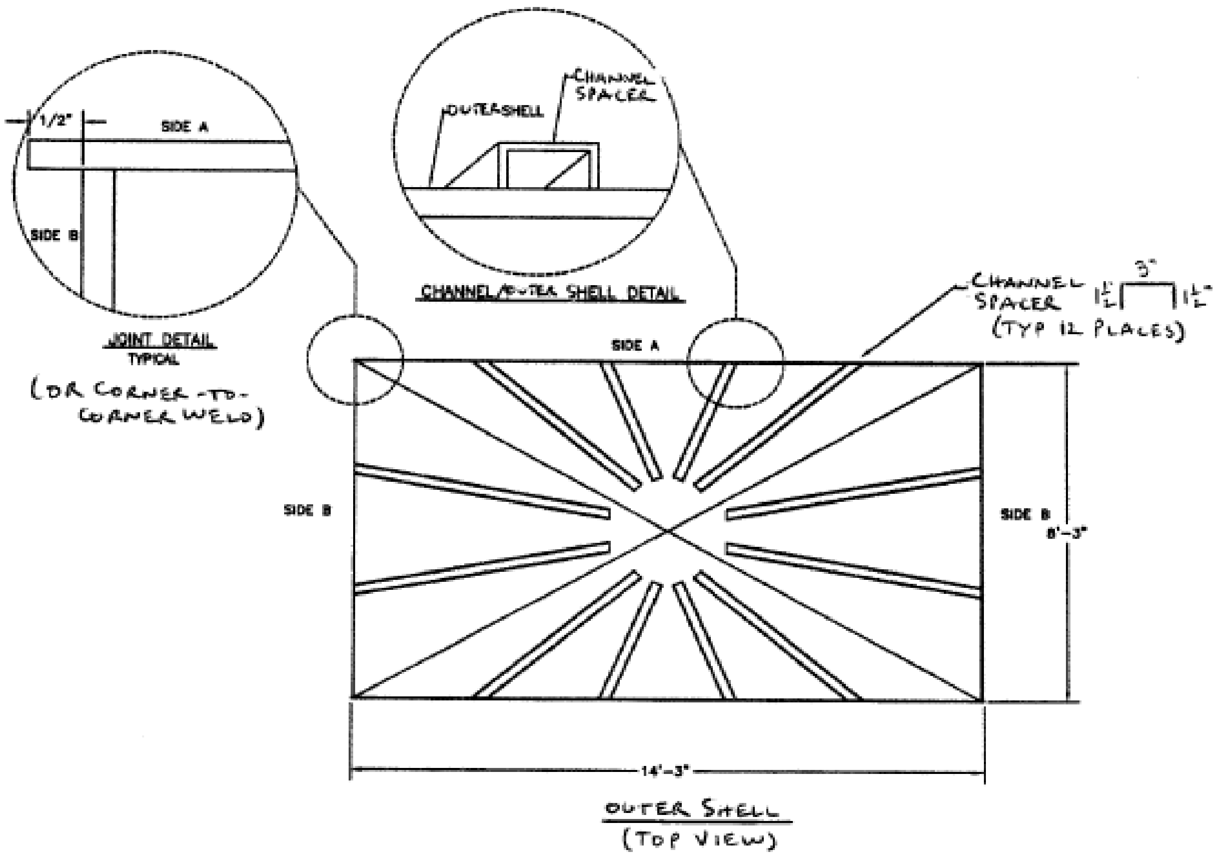


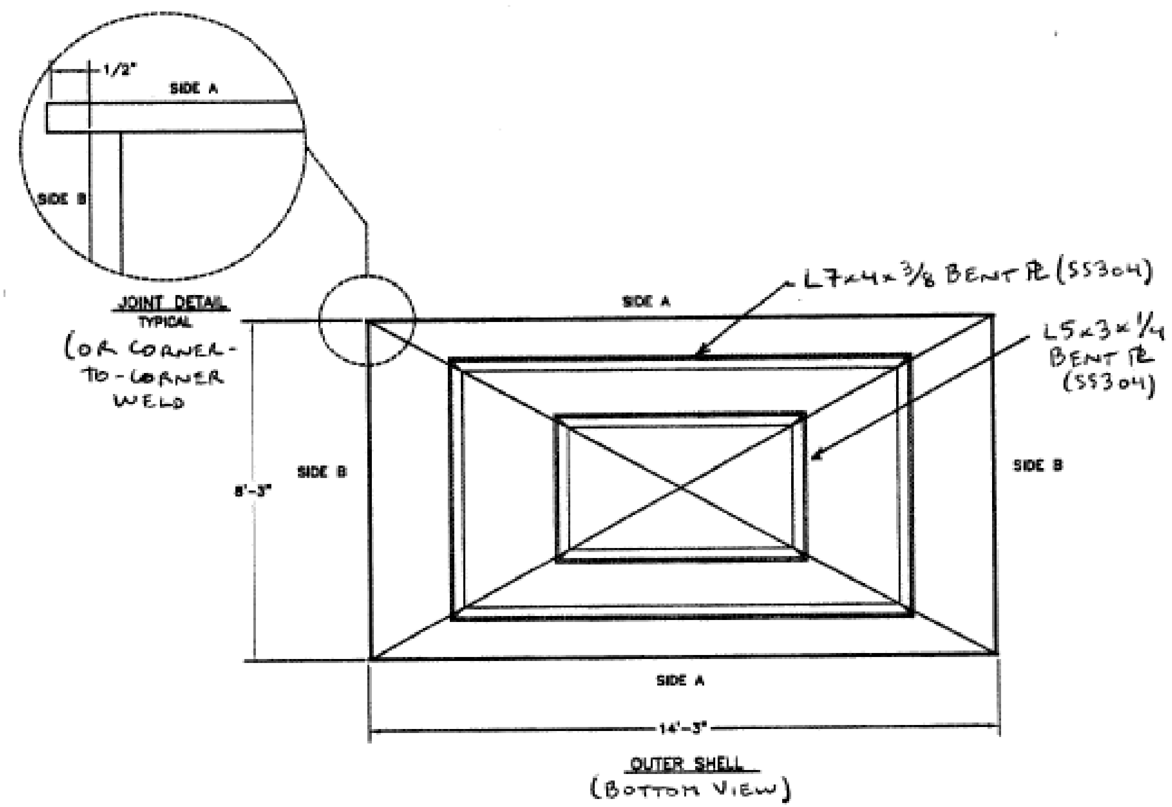
DETAIL -C-



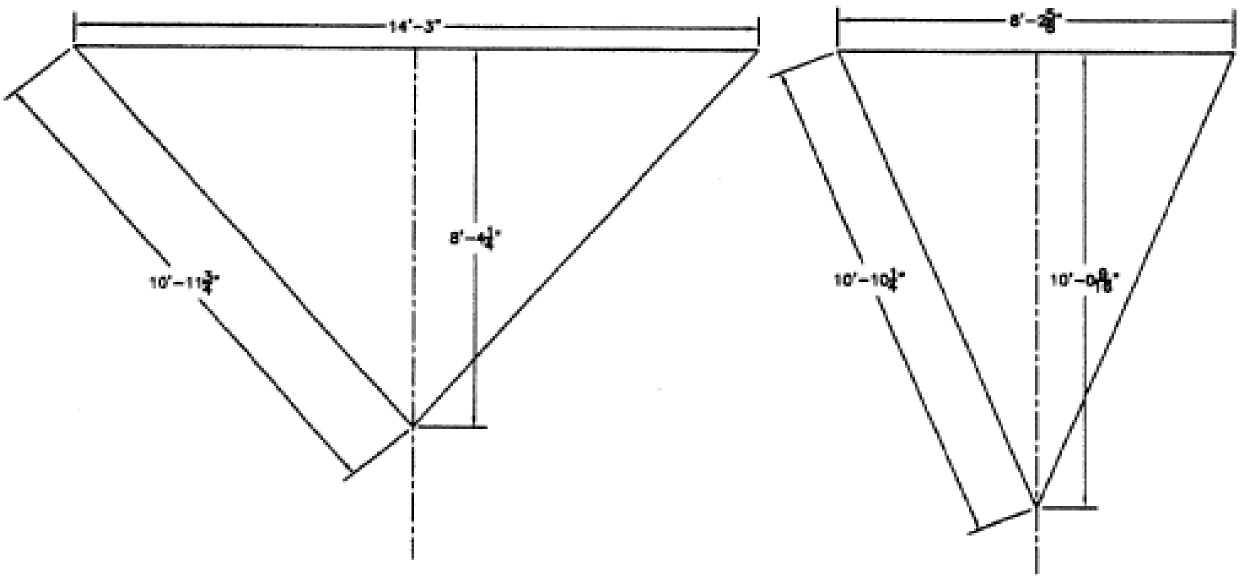
DETAIL -B-

Hopper Details, cont.





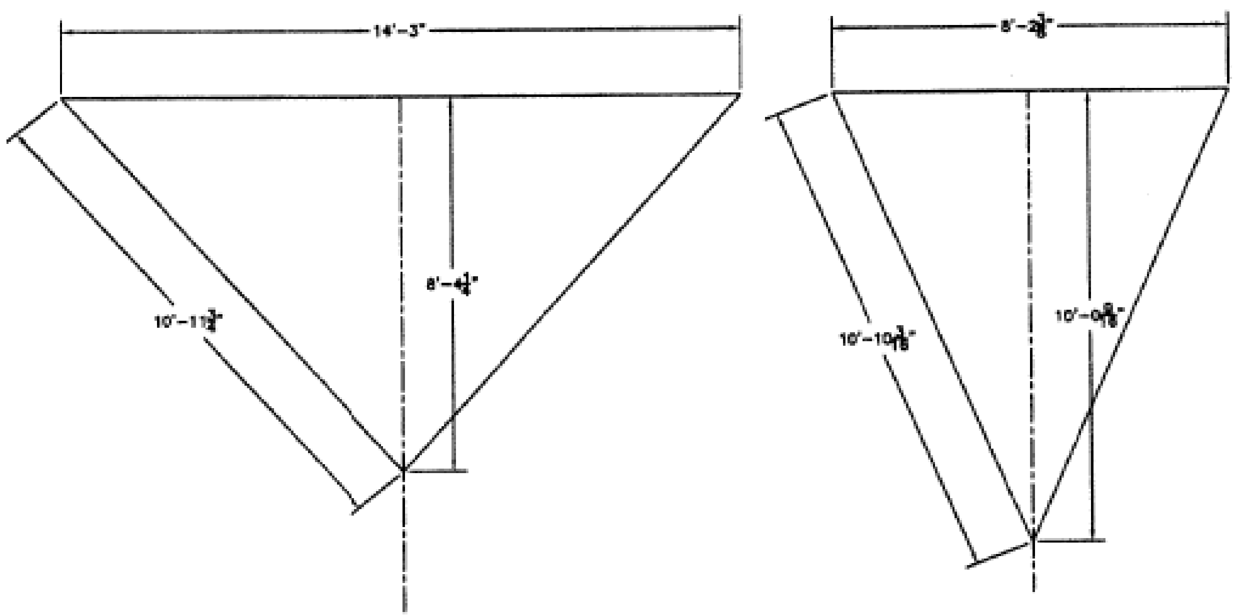
Hopper Details, cont.



SIDE A
3/8" PLT 316SS (2 NEEDED)

INNER SHELL

SIDE B
3/8" PLT 316SS (2 NEEDED)



SIDE A
1/4" PLT 304SS (2 NEEDED)

OUTER SHELL

SIDE B
1/4" PLT 304SS (2 NEEDED)

Design Hopper Components

Spacing of C3x1.5x1/4 Spacers Between Inner & Outer Walls

- Spacers are welded to 1/4" outer shell with min weld shown below
- Support spacing for 1/4" outer wall governs over 3/8" thick inner hopper wall
- Consider granular material with 5' head as governing condition for these checks

Check plate midway down hopper wall:

Max allowable stiffener spacing:

$L_s = (54000t^2/p)^{1/2} =$ 30.3 in

Where: $t =$ 0.25 in

$p =$ 3.68 psi

Max actual stiffener spacing = 17 in **< Allowable, OK**

Check midway between upper horz stiffener and grating:

Max allowable stiffener spacing:

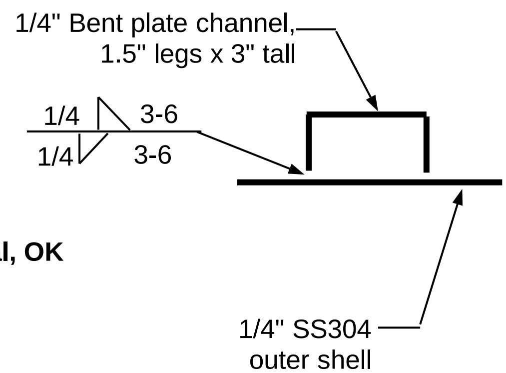
$L_s = (54000t^2/p)^{1/2} =$ 35.0 in

Where: $t =$ 0.25 in

$p =$ 2.76 psi

Max actual stiffener spacing = 29.3 in **< Allowable, OK**

Check C3x1.5x1/4 Stiffeners/Spacers Between Inner & Outer Walls



Channel Spacer Details

Short side of hopper

Check stiffener midway down hopper wall:

$f_b = M/S =$ 9845 psi

Where: $M = wL^2/8 =$ 12110 in-lbs

$w =$ 60.7 pli

$L =$ 40.0 in

$S =$ 1.23 in^3

$F_b = (0.7)(22{,}500\ psi) =$ 15750 psi **> Actual, OK**

Check midway between upper horz stiffener and grating:

$f_b = M/S =$ 12978 psi

Where: $M = wL^2/8 =$ 15963 in-lbs

$w =$ 80.0 pli

$L =$ 40.0 in

$S =$ 1.23 in^3

$F_b = (0.7)(22{,}500\ psi) =$ 15750 psi **> Actual, OK**

Long side of hopper

Check stiffener midway down hopper wall:

$f_b = M/S =$ 7053 psi

Where: $M = wL^2/8 =$ 8675 in-lbs

$w =$ 62.5 pli

$L =$ 33.3 in

$S =$ 1.23 in^3

$F_b = (0.7)(22{,}500\ psi) =$ 15750 psi **> Actual, OK**

Check midway between upper horz stiffener and grating:

$f_b = M/S =$ 9088 psi

Where: $M = wL^2/8 =$ 11178 in-lbs

$w =$ 80.5 pli

$L =$ 33.3 in

$S =$ 1.23 in^3

$F_b = (0.7)(22{,}500\ psi) =$ 15750 psi **> Actual, OK**

Check Hopper Components, cont.

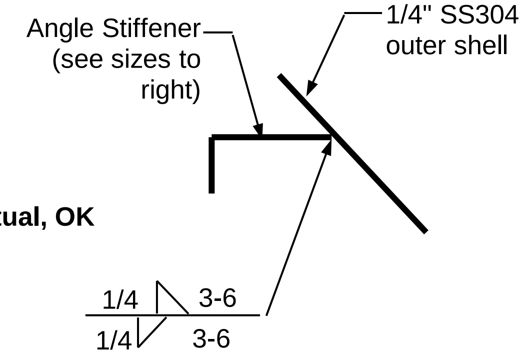
Angle Stiffeners on Outside of Exterior Shell

Upper stiffener (governing condition is long side)

$f_b = M/S =$	15587	psi	
Where: $M = wL^2/8 =$	199508	in-lbs	
$w =$	107.2	pli	
$L =$	122.0	in	
Try **L7x4x3/8** welded to 1/4" shell, $S =$	12.8	in^3	
$F_b = (0.7)(22{,}500\ psi) =$	15750	psi	**> Actual, OK**

Lower stiffener (governing condition is long side)

$f_b = M/S =$	15135	psi	
Where: $M = wL^2/8 =$	75071	in-lbs	
$w =$	137.9	pli	
$L =$	66.0	in	
Try **L5x3x1/4** welded to 1/4" shell, $S =$	4.96	in^3	
$F_b = (0.7)(22{,}500\ psi) =$	15750	psi	**> Actual, OK**



Exterior Stiffener Details

Top Compression Bar

Short side of hopper:	$f_b = M/S =$	8421	psi	
	Where: $M = wL^2/8 =$	117563	in-lbs	
	$w =$	96.0	pli	
	$L =$	99.0	in	
	Try FB 3/4"x 9" welded to 3/8" x 12.625" vert plate, $S =$	13.96	in^3	
	$F_b = (0.7)(22{,}500\ psi) =$	15750	psi	**> Actual, OK**
Long side of hopper:	$f_b = M/S =$	14464	psi	
	Where: $M = wL^2/8 =$	201923	in-lbs	
	$w =$	55.9	pli	
	$L =$	170.0	in	
	Try FB 3/4"x 9" welded to 3/8" x 12.625" vert plate, $S =$	13.96	in^3	
	$F_b = (0.7)(22{,}500\ psi) =$	15750	psi	**> Actual, OK**

3/8" x 12.625" Top Vertical Perimeter Plate

Max spacing of gussets for 5' of head pushing outward:

Max allowable gusset spacing:

$L_s = (54000t^2/p)^{1/2} =$	48.3	in	
Where: $t =$	0.375	in	
$p =$	3.25	psi	
Max actual stiffener spacing =	18	in (max)	**< Allowable, OK**

Check 18" spacing of gussets for forces due to hopper inner wall pulling inward:

$f_b = M/S =$	13134	psi	
Where: $M = wL^2/8 =$	3886	in-lbs	
$w =$	96.0	pli	
$L =$	18.0	in	
3/8" x 12.625" tall plate, $S =$	0.30	in^3	
$F_b = (0.7)(22{,}500\ psi) =$	15750	psi	**> Actual, OK**

Check Hopper Components, cont.

Grating Max span of bearing bars = 4.72 ft

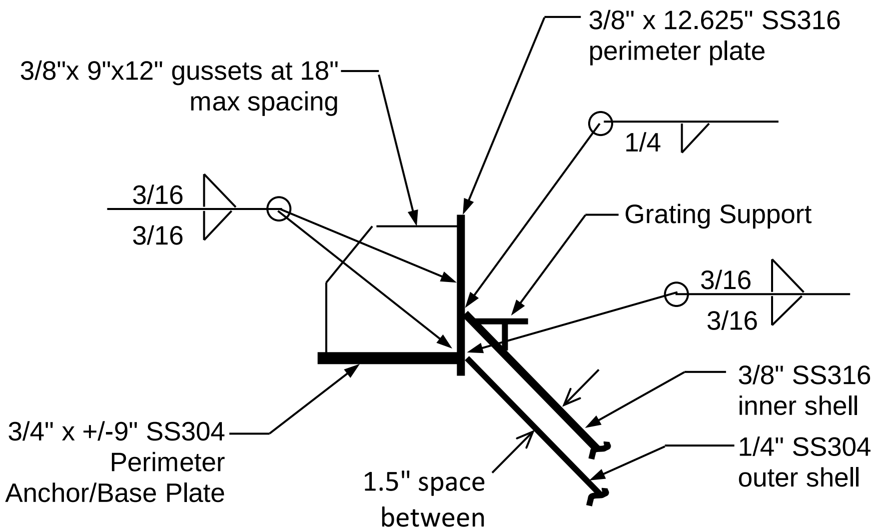
Use 1 1/4" x 3/16" Galvanized Stainless Steel Bar Grating (19-W-4)

→ Allowable uniform load = 325 psf > 100 psf √ OK

(see attached grating data sheet)

Grating Support Beam

$f_b = M/S =$	10408	psi
Where: $M = wL^2/8 =$	57867	in-lbs
w =	47.2	pli
L =	99.0	in
Try W6x9 (or shop fab'd equal), S =	5.56	in^3
$F_b = (0.7)(22{,}500\ psi) =$	15750	psi **> Actual, OK**



Section thru Top Edge of Hopper

Hopper Grating

Per chart below, 1 1/4 x 3/16 W-19-4 stainless steel grating is OK for up to 325 psf > 100 psf. √ OK

Stainless Steel Grating Load Table

19-4 / 19-2 LOAD TABLE

BEARING BAR SIZE		UNSUPPORTED SPAN													WEIGHT PER SQ. FT. (LBS.)							
		2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	8'-0"	9'-0"	19-4	19-2	15-4	15-2	11-4	11-2	7-4	7-2
3/4 X 1/8	U	395	253	175	129	99	78								4.0	4.8	4.9	5.7	6.4	7.2	9.7	10.7
	D	.114	.179	.257	.350	.457	.579															
	C	395	316	263	226	197	175															
	D	.091	.143	.206	.280	.366	.463															
3/4 X 3/16	U	592	379	263	193	148	117								5.6	6.4	6.9	7.7	9.2	10.0	14.5	16.0
	D	.114	.179	.257	.350	.457	.579															
	C	592	474	395	338	296	263															
	D	.091	.143	.206	.280	.366	.463															
1 X 1/8	U	702	449	312	229	175	139	112	93	78					5.1	5.9	6.2	7.1	8.2	9.0	12.9	14.2
	D	.086	.134	.193	.263	.343	.434	.536	.648	.771												
	C	702	561	468	401	351	312	281	255	234												
	D	.069	.107	.154	.210	.274	.347	.429	.519	.617												
1 X 3/16	U	1053	674	468	344	263	208	168	139	117					7.4	8.4	9.2	10.2	12.1	13.1	19.4	21.3
	D	.086	.134	.193	.263	.343	.434	.536	.648	.771												
	C	1053	842	702	602	526	468	421	383	351												
	D	.069	.107	.154	.210	.274	.347	.429	.519	.617												
1-1/4 X 1/8	U	1096	702	487	358	274	217	175	145	122	104	90			6.4	7.4	7.8	8.8	10.3	11.3	15.8	17.1
	D	.069	.107	.154	.210	.274	.347	.429	.519	.617	.724	.840										
	C	1096	877	731	627	548	487	439	399	365	337	313										
	D	.055	.086	.123	.168	.219	.278	.343	.415	.494	.579	.672										
1-1/4 X 3/16	U	1645	1053	731	537	411	325	263	217	183	156	134			9.0	10.0	11.2	12.2	14.9	15.9	23.8	25.7
	D	.069	.107	.154	.210	.274	.347	.429	.519	.617	.724	.840										
	C	1645	1316	1096	940	822	731	658	598	548	506	470										
	D	.055	.086	.123	.168	.219	.278	.343	.415	.494	.579	.672										
1-1/2 X 1/8	U	1579	1011	702	516	395	312	253	209	175	149	129	99	78	7.4	8.4	9.2	10.2	12.1	13.1	18.8	20.0
	D	.057	.089	.129	.175	.229	.289	.357	.432	.514	.604	.700	.914	1.157								
	C	1579	1263	1053	902	789	702	632	574	526	486	451	395	351								
	D	.046	.071	.103	.140	.183	.231	.286	.346	.411	.483	.560	.731	.926								
1-1/2 X 3/16	U	2368	1516	1053	773	592	468	379	313	263	224	193	148	117	11.1	12.5	13.7	15.1	18.1	19.6	28.1	30.1
	D	.057	.089	.129	.175	.229	.289	.357	.432	.514	.604	.700	.914	1.157								
	C	2368	1895	1579	1353	1184	1053	947	861	789	729	677	592	526								
	D	.046	.071	.103	.140	.183	.231	.286	.346	.411	.483	.560	.731	.926								
1-3/4 X 3/16	U	3224	2063	1433	1053	806	637	516	426	358	305	263	201	159	12.7	14.1	15.7	17.1	20.9	22.3	32.5	34.4
	D	.049	.077	.110	.150	.196	.248	.306	.370	.441	.517	.600	.784	.992								
	C	3224	2579	2149	1842	1612	1433	1289	1172	1075	992	921	806	716								
	D	.039	.061	.088	.120	.157	.198	.245	.296	.353	.414	.480	.627	.793								
2 X 3/16	U	4211	2695	1871	1375	1053	832	674	557	468	399	344	263	208	14.3	15.7	17.8	19.2	23.7	25.1	36.9	38.8
	D	.043	.067	.096	.131	.171	.217	.268	.324	.386	.453	.525	.686	.868								
	C	4211	3368	2807	2406	2105	1871	1684	1531	1404	1296	1203	1053	936								
	D	.034	.054	.077	.105	.137	.174	.214	.259	.309	.362	.420	.549	.694								
2-1/4 X 3/16	U	5329	3411	2368	1740	1332	1053	853	705	592	505	435	333	263	15.9	17.4	19.8	21.2	26.5	27.9	41.3	43.2
	D	.038	.060	.086	.117	.152	.193	.238	.288	.343	.402	.467	.610	.771								
	C	5329	4263	3553	3045	2664	2368	2132	1938	1776	1640	1523	1332	1184								
	D	.030	.048	.069	.093	.122	.154	.190	.230	.274	.322	.373	.488	.617								
2-1/2 X 3/16	U	6579	4211	2924	2148	1645	1300	1053	870	731	623	537	411	325	17.5	19.0	21.8	23.3	29.2	30.7	45.6	47.5
	D	.034	.054	.077	.105	.137	.174	.214	.259	.309	.362	.420	.549	.694								
	C	6579	5263	4386	3759	3289	2924	2632	2392	2193	2024	1880	1645	1462								
	D	.027	.043	.062	.084	.110	.139	.171	.207	.247	.290	.336	.439	.555								

LOADS AND DEFLECTIONS ARE THEORETICAL VALUES BASED ON 20,000 PSI UNIT STRESS. FOR PEDESTRIAN COMFORT DEFLECTIONS IN EXCESS OF 1/4" ARE NOT RECOMMENDED.

U = SAFE UNIFORM LOAD, LBS. PER SQ. FT.
C = SAFE CONCENTRATED MID-SPAN LOAD, LBS. PER FT. OF GRATING WIDTH
D = DEFLECTION IN INCHES

NOTE: WHEN GRATINGS WITH SERRATED BEARING BARS ARE SELECTED, THE DEPTH OF GRATING REQUIRED TO SERVICE A SPECIFIED LOAD WILL BE 1/4" GREATER THAN THAT SHOWN IN THE TABLES ABOVE.

CONVERSION TABLE

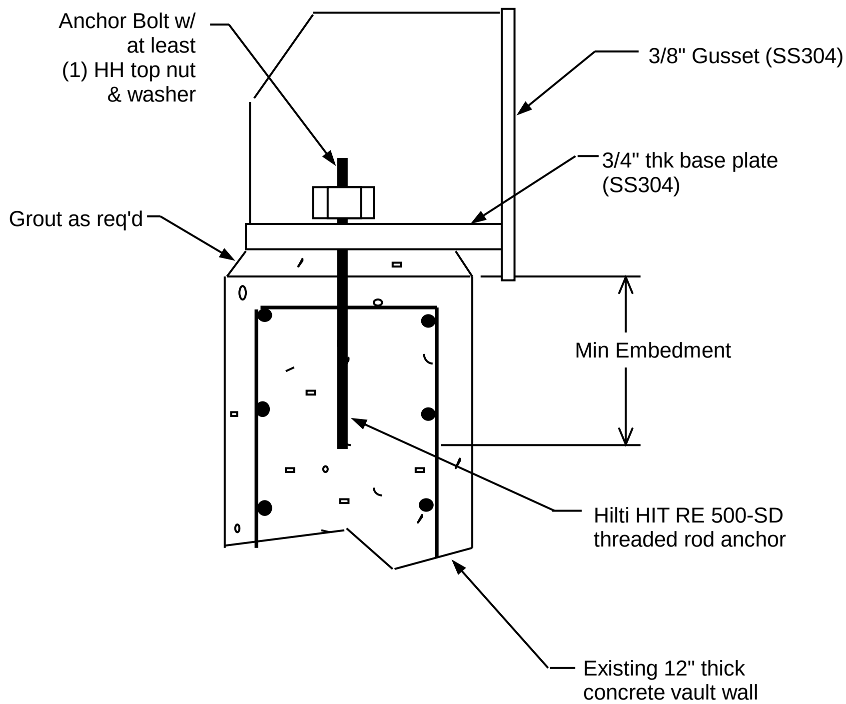
The loads shown above are for type 19-4 and 19-2 gratings. To determine the load carrying capacity for alternative bar spacings, multiply the loads given by the following conversion factors (DEFLECTION REMAINS CONSTANT): **FOR TYPES 15-4 AND 15-2: 1.26** **FOR TYPES 11-4 AND 11-2: 1.72** **FOR TYPES 7-4 AND 7-2: 2.71**

SELECTION GUIDE: 19-4 PLAIN SURFACE GRATING

For deflection of not more than 1/4" when subjected to the severest of the following: (1) the uniform loads below; (2) under concentrated mid-span loads of 300 lbs. up to 6'-0" span; or (3) 400 lbs. for spans 6'-0" and over.

SAFE UNIFORM LOAD LBS./SQ. FT.	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	8'-0"	9'-0"
50	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16
75	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16
100	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2-1/4 x 3/16	2-1/2 x 3/16
125	1 x 1/8	1 x 1/8	1 x 1/8	1 x 1/8	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16	–
150	1 x 1/8	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	2 x 3/16	2 x 3/16	2-1/2 x 3/16	–
200	1 x 1/8	1 x 1/8	1 x 1/8	1-1/4 x 1/8	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	1-3/4 x 3/16	2 x 3/16	2-1/4 x 3/16	–	–
300	1 x 1/8	1 x 1/8	1 x 3/16	1-1/4 x 3/16	1-1/2 x 3/16	1-3/4 x 3/16	2 x 3/16	2 x 3/16	2-1/4 x 3/16	2-1/2 x 3/16	–	–

Anchorage Summary - Hilti Epoxy Anchor Option



Anchor Bolt Summary

	Use (12) - 0.75 inch diameter threaded rod Anchor Bolts Around Base Plate		
	Material = ASTM F593 CW2 (316) (threaded rod)		
(Recommended min)	Projection above concrete =	3	in + grout thickness (if this vessel is grouted)
	Min Embedment =	6.0	in
	Min Edge Distance =	6.0	in (all sides of all anchor bolts)
	Min Concrete f'_c =	4000	psi

Tank Anchorage (Hilti Epoxy Anchors)

Check Anchor Bolts per IBC 2012 "Strength Design", ACI 318-11, Appendix D & Hilti ESR-2322.

Trial Input Data

Bolt diameter (d_o) =	0.750	in dia.	
Bolt material =	ASTM F593 CW2 (316)		(threaded rod)
Yield strength of bolt material =	45	ksi	
Bolt embedment depth (h_{ef}) =	6	in	
Minimum bolt edge distance (c_1) =	6	in	
Cross-sectional area of bolt (A_d) =	0.44	in^2	
Tensile stress area of bolt (A_{se}) =	0.334	in^2	
Minimum root area of bolt (A_r) =	0.302	in^2	
Minimum Concrete f_c' =	4000	psi	
Seismic overturning moment (M_s) =	16.91	ft-k	
Seismic Base Shear (V_s) =	9.66	k	
Empty wt. of tank =	7.5	k	
Full wt. product & tank (W_T) =	32.8	k	

Seis. pullout for IBC strength level equations = $1.0E_{tension}$ - 0.6D =	0.01	k/bolt
Where: $E_{tension}$ =	0.50	k/bolt
D =	0.81	k/bolt
Seismic shear used in IBC strength level equations = $1.0E_{shear}$ =	1.21	k/bolt

(conservatively ignore resisting friction due to weight of tank & product)

Total strength level design pullout (N_u) =	0.01	k/bolt
Total strength level design shear (V_u) =	1.21	k/bolt

Per IBC 2012 Anchor Bolts are Acceptable If:

Anchor bolt tensile strength is greater than factored tension load: $\phi N_n > N_u$

and anchor bolt shear strength is greater than factored shear load: $\phi V_n > V_u$

And if interaction checks are satisfied (see loads below):

Case 1) Steel strength:	$N_u/\phi N_s + V_u/\phi V_s$ =	**0.118**	**< 1.2 -- OK**
Case 2) Concrete breakout:	$N_u/\phi N_{cb} + V_u/\phi V_{cb}$ =	**0.284**	**< 1.2 -- OK**

<u>Therefore Anchors are OK per Interaction Checks</u>

Tank Anchorage (Hilti Epoxy), cont.

Check anchor bolt tension:

Check following cases:
1) Steel strength of anchor in tension: $\phi N_s > N_u$
2) Concrete breakout strength of anchor in tension: $\phi N_{cb} > N_u$
3) Pullout strength of anchor in tension: $\phi N_{pn} > N_u$
4) Concrete side-face blowout strength of anchor in tension: $\phi N_{sb} > N_u$

Factored seismic uplift load per bolt (N_u) = **0.01** k (see above)

Case (1): Steel strength of anchor in tension: $\phi N_s > N_u$

$\phi N_s = \phi A_{se} f_{ut}$ =	**18.56 k**	**>**	**0.01 k -- OK**
Where: ϕ =	0.65		
f_{ut} =	85.5 ksi		
ESR-1682 Test Results (for reference only):	**12.39 k**	**>**	**0.01 k -- OK**

Case (2): Concrete breakout strength of anchor in tension: $\phi N_{cb} > N_u$

$\phi N_{cb} = (\phi)(A_{Nc}/A_{Nco})(\psi_{ed,N})(\psi_{c,N})(\psi_{cp,N})(N_b)$ =	**9.99 k**	**>**	**0.01 k -- OK**
Where: ϕ =	0.65		
A_{Nc} =	225 in^2		
$A_{Nco} = 9h_{ef}^2$ =	324 in^2		
$\psi_{ed,N} = 0.7+(0.3c)/(1.5h_{ef})$ =	1.0		
$\psi_{c,N}$ =	1.4		
$\psi_{cp,N}$ =	1.0		
$N_b = k(f'_c)^{1/2}(h_{ef})^{1.5}$ =	15.8 k		
k =	17		

Case (3): Pullout strength of anchor in tension (see Hilti ESR-2322,4.1.4):

$\phi N_a = (\phi)(A_{Na}/A_{Nao})(\varphi_{p,Na} N_{ao})$ =	**14.38 k**	**>**	**0.01 k -- OK**
Where: ϕ =	0.65		
$\varphi_{p,Na}$ =	1.4		
A_{Na} =	245 in^2		
A_{Nao} =	245 in^2		
$N_{ao} = \pi \tau_{kcr} d h_{ef}$ =	15.80 k		

Case (4): Concrete side-face blowout strength of anchor in tension: $\phi N_{sb} > N_u$

$\phi N_{sb} = \phi 160c(A_{brg})^{0.5}(f'_c)^{0.5}$ = **N/A k**

Equation does not apply since bolts are post-installed & not headed.
Since edge distance is 6 in, side blowout is not an issue
(ref. edge distance requirements in Hilti data sheets).

<u>Therefore Anchors are OK for Tension Loads</u>

Tank Anchorage (Hilti Epoxy), cont.

Check anchor bolt shear:

Check following cases:
1) Steel strength of anchor in shear: $\phi V_s > V_u$
2) Concrete breakout strength of anchor in shear: $\phi V_{cb} > V_u$
3) Concrete pryout strength of anchor in shear: $\phi V_{cp} > V_u$

Factored seismic shear load per bolt (V_u) = **1.21** k (see above)

Case (1): Steel strength of anchor in shear: $\phi V_s > V_u$

Check #1: $\phi V_s = \phi 0.6 A_{se} f_{ut}$ =	**10.28 k**	**>**	**1.21 k -- OK**
Where: ϕ =	0.60		
f_{ut} =	85.5 ksi		
Check #2: ϕV_s =	**10.24 k**	**>**	**1.21 k -- OK**
Where: V_s =	17.06 k (see Hilti ESR-2322, Table 7)		
ESR-1682 Test Results (for reference only):	**6.38 k**	**>**	**1.21 k -- OK**

Case (2): Concrete breakout strength of anchor in shear: $\phi V_{cb} > V_u$

$\phi V_{cb} = (\phi)(A_{Vc}/A_{Vco})(\varphi_{edV}\varphi_{cV}V_b)$ =	**4.27 k**	**>**	**1.21 k -- OK**
Where: ϕ =	0.60		
A_V =	135 in^2 (based on min dim's)		
A_{Vo} =	162 in^2		
φ_{edV} =	1.0		
φ_{ecV} =	1.0		
$V_b = 7(\ell/d_o)^{0.2}(d_o)^{1/2}(f'_c)^{1/2}(c_1)^{1.5}$ =	8.5 k		
ℓ =	6.0 in		

Case 3) Concrete pryout strength of anchor in shear: $\phi V_{cp} > V_u$

Check #1: $\phi V_{cp} = (\phi k_{cp} N_{cb})$ =	**18.44 k**	**>**	**1.21 k -- OK**
Where: ϕ =	0.60		
k_{cp} =	2.0		
$N_{cb} = \phi N_{cb}/\phi$ =	15.4		
Check #2: $\phi V_{cp} = (\phi k_{cp} N_a)$ =	**26.55 k**	**>**	**1.21 k -- OK**
$N_a = (A_{Na}/A_{Nao})(\varphi_{pNa} N_{ao})$ =	22.12 k		
$N_{ao} = \tau_{kcr} \pi d h_{ef}$ =	15.80 k		
τ_{kcr} =	1.12		
φ_{pNa} =	1.00		
A_{Na} =	245 in^2		
A_{Nao} =	245 in^2		

<u>Therefore Anchors are OK for Shear Loads</u>